

FIRST QUARTERLY REPORT

RESEARCH AND DEVELOPMENT

IN

CdS PHOTOVOLTAIC FILM CELLS

By

T. A. Griffin, R. W. Olmsted, J. C. Schaefer

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

May 19, 1964 to August 19, 1964

CONTRACT NAS 3-4177

N64-34004

Facility Form 602

(ACCESSION NUMBER)

29

(PAGES)

CB 54173

(NASA CR OR TMX OR AD NUMBER)

(THRU)

1

(CODE)

22

(CATEGORY)

OTS PRICE

\$

2.00

XEROX

\$

0.50

MICROFILM

THE HARSHAW CHEMICAL CO.

N O T I C E

This report was prepared as an account of Government sponsored work. Neither the United States, nor the National Aeronautics and Space Administration (NASA), nor any person acting on behalf of NASA:

- A.) Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B.) Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used above, "person acting on behalf of NASA" includes any employee or contractor of NASA, or employee of such contractor, to the extent that such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with NASA, or his employment with such contractor.

Requests for copies of this report should be referred to:

National Aeronautics and Space Administration
Office of Scientific and Technical Information
Attention: AFSS-A
Washington, D.C. 20546

26858
CASE FILE COPY

FIRST QUARTERLY REPORT

RESEARCH AND DEVELOPMENT
in
CdS PHOTOVOLTAIC FILM CELLS

by

T. A. Griffin, R. W. Olmsted, J. C. Schaefer

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

May 19, 1964 to August 19, 1964

CONTRACT NAS 3-4177

Technical Management
NASA Lewis Research Center
Cleveland, Ohio
Space Power Systems Division
Clifford Swartz

Harshaw Chemical Company
Crystal-Solid State Division
1945 E. 97th Street
Cleveland 6, Ohio

FOREWORD

The work of this project has been carried out at the Crystal-Solid State Research Laboratory of The Harshaw Chemical Company. Dr. J. M. McKenzie is the Technical Director of the laboratory. The work was sponsored by the Lewis Research Laboratory of NASA with Dr. Andrew E. Potter acting as Technical Advisor, and Clifford Swartz acting as Project Manager. Project direction has been provided by Mr. J. C. Schaefer. Mr. T. A. Griffin has acted as the Project Supervision Engineer and Principal Investigator.

The following Harshaw Chemical Company personnel have contributed to this program: R. W. Olmsted, W. W. Baldauf, D. H. Dickey, and R. F. Belt.

LIST OF FIGURES

<u>FIGURE</u>	<u>TITLE</u>	<u>PAGE</u>
I	Transmission of H-film and Pyre ML Varnish.	13
II	Pressurized Solar Cell Test Apparatus	19

LIST OF TABLES

<u>TABLE</u>	<u>TITLE</u>	<u>PAGE</u>
I	Film and Cell Properties Vs. Pressure Bursts	9
II	Data for Pressure Tests.	15
III	Data for Alpha Solder Tests, Electroplated Barrier . . .	16
IV	Data for Alpha Solder Tests, Chemiplated Barrier	17

TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION	1
CHEMICAL MILLING SUBSTRATES	3
Process	3
Problems	4
ELECTROPLATED COLLECTORS	5
FILM PROPERTIES	7
OTHER SUBSTRATE MATERIALS	10
LAMINATION	11
Equipment	11
Plastics.	11
Pressure Tests	12
Solder Tests	14
PILOT LINE	18
WORK PLANNED FOR THE NEXT QUARTER	20
REFERENCES	21

RESEARCH AND DEVELOPMENT
IN
CdS PHOTOVOLTAIC FILM CELLS

by T. A. Griffin, R. W. Olmsted, and J. C. Schaefer

INTRODUCTION

This report covers the first quarter of work on contract NAS 3-4177 which is a follow on contract to NAS 3-2493. During the previous period the CdS thin film cells had been improved in power to weight ratio so that they could be considered as equivalent to silicon solar cells. Any improvement in output efficiency and package design coupled with the CdS film cell's radiation resistance should insure its use in future space missions.

In the previous work, cells over 5% efficiency and over twenty-five watts per pound have been produced. The present work will place emphasis on making the film cell more uniform and reliable under launch and space conditions. The major objectives are to fabricate light weight, flexible, uniformly high efficiency, low cost cells capable of operating in space conditions for long periods of time.

This program will be implemented by a performance in-house test program at NASA's Lewis Laboratory. The results of tests such as ultraviolet exposure, electron and proton bombardment, and thermal cycling in high vacuum will be used to modify cell materials and construction in order to find those combinations that are most compatible with prolonged operation under space conditions.

During the first quarter, many significant developments have been realized bringing the cell much closer to the ultimate goals. These improvements include: Lighter substrates yielding over forty watts per pound on 3" x 3" cells; electroplated grids that have produced 3% cells thereby promising to reduce the cost by elimination of the costly gold electroformed mesh; and a new cell packaging design that has withstood hundreds of thermal cycles between +65°C and -70°C conducted in a vacuum chamber.

CHEMICAL MILLING SUBSTRATES

Much effort has been directed toward increasing the watts per pound ratio by using thinner, less dense, substrates. It was found that thinner molybdenum (one mil) presented a large handling problem.⁽¹⁾ Other, less dense, metals also presented problems such as poor thermal match and poor adherence due to surface conditions.⁽²⁾

Since two mil molybdenum was easy to handle as a substrate, a process was developed whereby the thicker molybdenum was retained through the entire cell fabrication procedure. Then immediately before or after lamination, the back of the cell (the molybdenum) was chemically milled to the desired thinness.⁽³⁾ This effectively reduced the weight of the cell and avoided the difficulties of working with extremely thin metal foils during evaporation and barrier formation procedures. Although a fine control has not been established for this process as yet, cells have been made that demonstrate over forty watts per pound. A 3" x 3" cell that was produced by this method and yielded forty-one watts per pound was delivered to the contract monitor this quarter. Completed cells (3" x 3") have been found to weigh less than two grams when they are chemically milled.

Process

The milling solution is composed of 50% HNO_3 and 50% H_2O by volume. Stronger nitric acid baths are too fast for proper control and at the same time yield pitted surfaces. There are indications that the 50% solution may also be too strong causing excessive heat to develop during milling.

At present, the best procedure requires the lamination of one mil H-film and one-half mil nylon on the face of the cell only. A narrow picture frame

of plastic is used to seal the edges of the substrate to the H-film on the face of the cell. The cell is then dipped into the etching solution for thirty seconds, rinsed in water, dipped into HCl and then rinsed again in water. This is repeated until the substrate is at the desired thickness. One method used to control the thickness requires the placement of a piece of molybdenum slightly thinner than the substrate into the etching solution along with the cell. When this piece disappears, then the cell substrate thickness is approximately equal to the original difference in the cell substrate and the piece of molybdenum.

Problems

When the 2 mil molybdenum substrate is milled to the range of 0.3 to 0.7 mils, it has a tendency to curl. Reducing the thickness to less than 0.3 alleviates the curling problem. If the molybdenum is milled much thinner than 0.3 mil, the CdS film tends to separate from the substrate. This may be connected with the heat generated during etching.

Another problem is that the etching solution attacks the nylon. For this reason, the nylon must cover only the front of the cell and not be allowed to overlap. It is best to seal the edges with a plastic picture frame on the back of the molybdenum.

Earlier, the cells were tapped to acid-resistant boards and chemically milled before lamination. It has proven easier to reverse the procedure and laminate first since there is an increased tendency for the CdS to peel after milling.

It would be advantageous to use a much slower etchant after the molybdenum is milled below one-half mil.

In summary, it might be noted that while this milling process is still not free of problems, it is inherently simple. It reduces the handling problems and produces the same results as working with thin foils. It opens new possibilities in power-to-weight ratios, and even in cell construction. Earlier, it was reported that a rear wall cell was fabricated by this method utilizing photoresist masking techniques.⁽⁴⁾ There are several rear wall and front wall combination cells that can be constructed.

ELECTROPLATED COLLECTORS

Much of the effort this quarter was directed toward electroplating gold collectors on the cell barrier to replace the costly electroformed mesh.

In addition to the economic advantage this grid offers, there are indications of greatly increased cell thermal cycle life. The results of thermal cycling tests at Lewis Laboratory indicate that the heavy gold mesh may be a source of shorting caused by the movements of the mesh and other cell materials against each other during the heating and cooling cycles. The electroplated grid does not appear to be so affected and should contribute toward making the CdS film cell a more reliable space power source.

The collector can be formed by electroplating through a photoresist mask. The plating current must be kept low, less than 2 ma.cm^{-2} . The two metals extensively used have been copper and gold. Copper is less satisfactory because it seems to alter the barrier. When copper is used, the cell generates an exponential I-V curve, but the curve does not appear to fit the usual equation. Initially, the gold electroplated grids exhibited a series resistance, but longer plating time has eliminated this problem for the 1" x 1" samples.

When 3" x 3" cells were used, new difficulties were encountered. The frequency of the shorted cells greatly increased. In fact, the majority of the 3" x 3" cells that are gridded in this manner exhibit partial shorts immediately after plating. It has been discovered that most of these shorts can be burned out with a pulse of high current. This is most likely a film problem and not related to the grid electroplating process. Once the short is burned out, it does not reappear.

The most serious problem remaining for electroplated grids on 3" x 3" cells is the development of a suitable bus bar network. The bus bars are necessary to reduce the series resistance associated with the relatively thin grids. Reduction of the series resistance with thicker grids requires prohibitively long plating times and frequently results in badly shorted cells, and reduced grid transmission. The most efficient bus bars used to date have been silver foil strips laminated in place over the electroplated grid. Attempts to solder the foil to the gridded foil revealed that there is a problem involving the amount of solder. An excess amount of solder invariably attacks the barrier. It has been demonstrated that these silver strips can be successfully spot welded to the gold grid without any harm to the cells.⁽⁵⁾ The possibility of ultrasonic welding will also be investigated for this purpose.

Ruled silver print and sprayed-on conductive epoxy have been used for bus bars and have been found to be unsatisfactory.

Recently there was a suspicion that the sheet resistance of the barrier was higher than usual especially in the case of the chemiplated barrier. Several cells were measured and the results showed that both barrier type cells had sheet resistances in the order of 1000 ohms per square. This is the value usually attained.

Electroplating 70 lines per inch gold grids with more than 85% transmission is approaching the status of a routine operation. A 3" x 3" cell with an electroplated grid and silver foil bus bar of 3% has been made. The introduction of electroplated grids has greatly lowered the yield factor for good cells.

Nine samples of 3" x 3" cells with electroplated grids were delivered to Lewis Laboratory for thermal and other tests. Preliminary results indicate that much of the difficulties that appeared in the cells during hundreds of thermal cycles are eliminated by substituting the electroplated grid for the mesh that laminated to the barrier.

Several cells with chemiplated barriers have been produced with the electroplated grids but much difficulty has been associated with this effort.

The combination of the chemical milling and electroplated grid should make a greatly improved space package. Cells incorporating these features are being prepared for extended thermal cycling under simulated space conditions.

FILM PROPERTIES

When the filaments are heated in the vacuum chamber, large pressure bursts due to outgassing of the CdS are noted. The magnitude of these bursts depends on the rate of filament heating. The question arose as to how much effect these pressure changes may have had on the properties of the film and the resultant cells.

A series of evaporations were made utilizing various rates of heating which resulted in bursts of varying magnitude. Hall samples were made for each evaporation. Cells were fabricated with the films produced. The films were also examined optically and by x-ray techniques. Table I shows some typical results.

The pressure bursts ranged from as high as 44 microns to less than 1 micron. All the pressures were read on the same thermocouple. In general, the

evaporation cycles were started in the 10^{-5} mm. pressure range.

The resistivities were found to be lower than the expected 1000 ohm-centimeters by a factor of ten. The mobilities were rather consistent, falling in the 0.07 to 0.14 $\text{cm}^2 \text{ volt-sec}^{-1}$ range. The film produced during the smallest pressure burst had the highest mobility. The carrier concentrations all were in the 10^{17} cm^{-3} range.

The best cells were from the largest and the smallest burst.

Samples of these vapor deposited CdS thin films were examined by back reflection x-ray techniques. All samples were mounted without disturbing either the glass substrate or the CdS deposit. Since the depth of penetration of $\text{CuK}\alpha$ x-rays in CdS is no more than about 25 μ , it may be seen that the results are more characteristic of the material in the last portion of the evaporation. The actual results showed that all lines in the patterns were from planes oriented randomly. The planes ordinarily observed in the back reflection pattern are (404) + (217), (315), and (306) + (321). A large fraction of (002) planes are nearly always parallel to the substrate. For samples N-18, N-22, and N-24, an increasing amount of preferred orientation was found in the back reflection region. This indicated that some form of biaxial orientation was occurring. Not only was the c-axis of crystallites perpendicular to the substrate, but the a-axis was also more frequent in particular directions in the plane of the film. It might be said that the films were more perfect in structure. Similar results have been found for CdS thin films epitaxially deposited on (001) faces of oriented CdS single crystals.

TABLE I

Film and Cell Properties Vs. Pressure Bursts

Film No.	Fil Rise Time Sec.	Max. Pressure μ	Duration of Burst Sec.	Film Thick-ness μ	Resis-tivity ohm-cm	Carrier Cong. cm^{-3}	Mobility $\text{cm}^2\text{-l volt-sec}$	OCV Volts	Current Density ma/cm^2	Eff. %
N16	10	44	.75	22	130	____*	<0.1	0.44	10.0	2.6
N14	20	24	68	20	250	3×10^{17}	0.7	0.45	6.85	1.8
N15	40	27	94	21	520	____*	<0.1	0.44	8.5	2.1
N17	60	28	60	27	95	6×10^{17}	0.1	0.42	6.4	1.5
N18	90	4	75	26	140	4×10^{17}	0.1	0.44	6.8	1.6
N19	120	3	75	23	230	____*	<0.1	0.44	6.7	1.8
N22	180	<1	200	20	190	5×10^{17}	0.07	0.44	6.7	1.9
N24	300	<1	200	22	220	2×10^{17}	0.14	0.45	9.8	2.3

* Mobility was too low to measure

In order to check the portion of the CdS thin film which was deposited first (that closest to the substrate), films were removed from the glass substrate by dipping in liquid N₂. Again, the back reflection x-ray patterns were taken and found to correspond to those of the randomly oriented type. This result may have been fortuitous because thermal shock can disturb the orientation somewhat. In either case, further work should be done on examination of the early stages of thin film growth where orientations should be important. This would emphasize more the effects of pressure changes observed early in the evaporations.

OTHER SUBSTRATE MATERIALS

As mentioned when chemical milling was discussed, perhaps the search for other substrate materials is not as important as it was previously. If molybdenum can be milled readily, then there is no need for working with thinner molybdenum. However, several cells were fabricated on 0.001" molybdenum during this quarter. In addition to handling difficulties, a problem of adherence seems to be inherent in the thin substrates and it seems to emanate from the surface condition. The open circuit voltages were also low indicating that there may have been pinholes in the films. This again could be a result of the surface condition of the molybdenum. As mentioned previously, there appears to be a different surface on two mil and one mil molybdenum even though both foils are cleaned in exactly the same manner.

Cells that were made on titanium have degraded about 50% and have not recovered despite treatment. There appears to be more involved than the reversible moisture damage that occurs in cells on molybdenum. These films will be stripped off and examined.

LAMINATION

Equipment

The present program requires the development of an impulse type laminator. During this period various product and material inquiries resulted in the discovery that equipment of a similar nature had been developed for large areas. Certain modifications of this equipment can make it possible to laminate one square foot areas. This equipment promises to provide improvements in the quality of lamination and operating speed.

Plastics

Since the electroplated grid is being used, the plastic is not necessary to hold the collector mesh to the surface of the cell. The possibility exists that the plastic encapsulation will not be desirable in the future. For this reason, some high temperature polyimide varnish, Pyre M.L., which is similar to H-film, was obtained.⁽⁶⁾ It was hoped that thin films of this varnish might make good moisture barriers.

Three 3" x 3" cells with photoetched grids were preheated to 175°C for one hour. Cell "A" was coated with a 100% mixture of Pyre M.L., and Cell "B" was coated with a 75% mixture of Pyre, M.L. and 25% Dimethylformamide. Cell "C" was coated with 50% Pyre M.L. and 50% DMF. All three coatings were spun on the cells with a thickness of less than 0.2 mil. All cells were then cured at 200°C for three hours. The electrical response was low but showed no degradation due to the varnish.

The three cells were then immersed in H₂O for 48 hours. Data taken at the end of the test showed a significant degradation. The average of the three cells was 1.50% efficiency before test and 0.3% after test. The test will be continued on higher efficiency cells. The indications are that the layers of this varnish are not good moisture barriers.

Attempts will be made to use the varnish over cells that have been laminated in nylon only.

The transmission of the Pyre M.L. varnish was checked and compared with that of H-film.⁽⁷⁾ As can be seen from Figure 1, the varnish transmits further into the blue to about 425 millimicrons while the H-film cuts off at about 480 millimicrons. It was reported that the yellow color of the H-film results from impurities and develops during curing. For this reason, some Pyre M.L. film was used to coat the cells since the possibility exists that all of the properties of the fully cured H-film are not necessary for protection of the cells. These Pyre M.L. coatings were much lighter in color than the H-film and their absorption edge was shifted toward the blue.

Some cells were coated with films made from Pyre M.L. varnish. These films cracked and dark spots appeared on the surface upon lamination. The films also became very brittle. When films made from the Pyre M.L. varnish were cured in an oven at 100°C for several hours they also became very brittle and changed to a darker yellow.

More work will be done using Pyre M.L. varnish as a replacement for H-film.

Krylon and acrylic spray coatings were also put on cells. After 72 hours in water, the cells were completely degraded.

A film of polydimethylphenol ether was obtained from NASA and laminated. This material has been reported to have many of the properties of H-film, plus the advantage of being almost colorless.

Upon lamination, it became very brittle, similar to the results obtained with polystyrene.

Pressure Tests

There were some suspicions that the pressure (100 psi) used to laminate was not optimum. Four 1-1/2" x 3" cells were pressure tested and I-V curves obtained for each cell. Each cell was then laminated at a different pressure

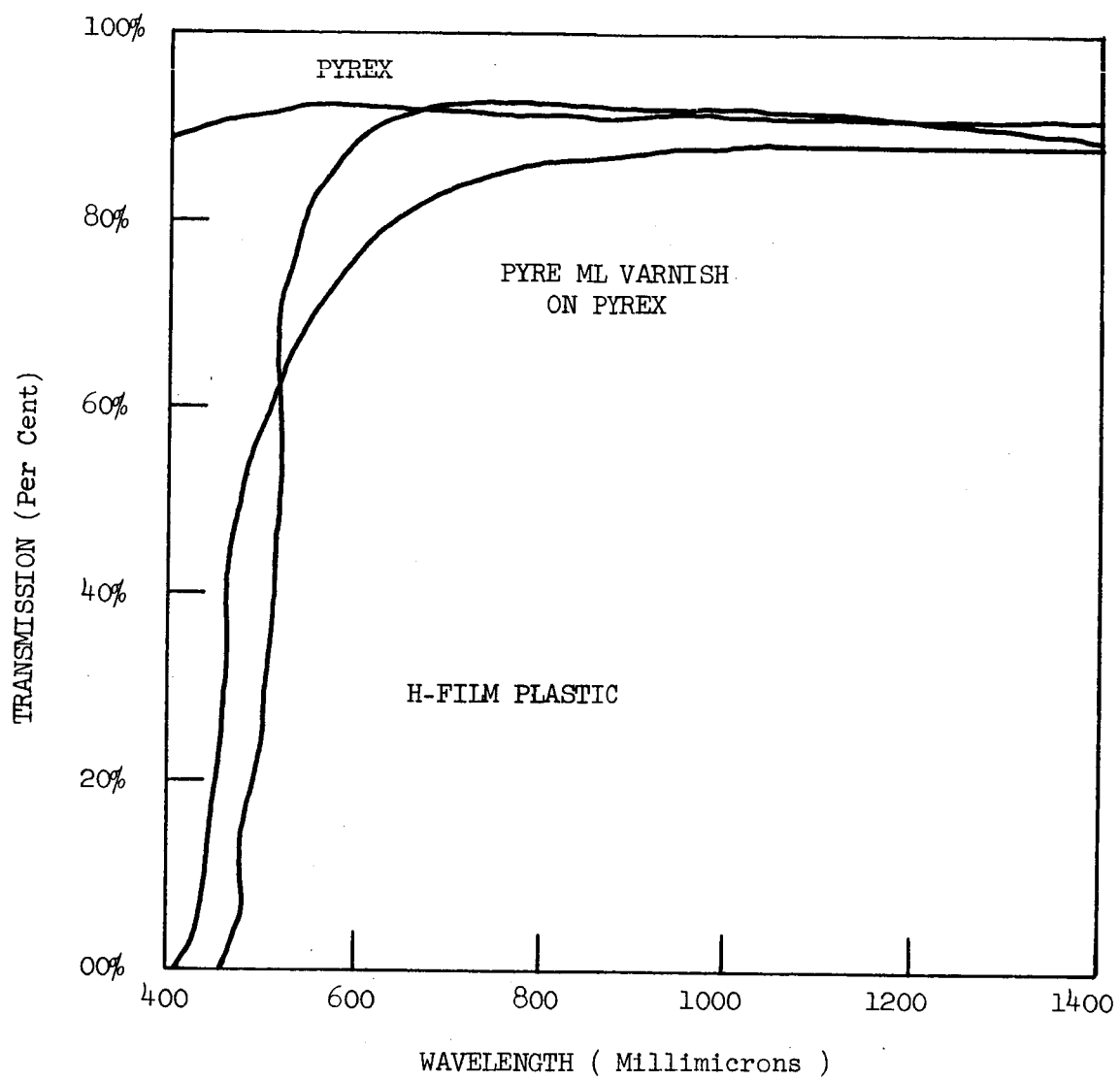


FIG I

TRANSMISSION OF H-FILM AND PYRE ML VARNISH

(100 psi, 150 psi, 200 psi, and 250 psi), I-V curves obtained and compared with the original I-V results. The test showed increases for all cells from their original efficiency (see Table II). However, the pressure range between 100 psi and 200 psi showed the greatest increase and this pressure range should be further investigated.

Solder Tests

The solder used to hold the silver lead to the gold mesh is an Alpha solder containing indium. The barrier was damaged when this material was used to hold the silver leads to the thin electroplated grids. Darkened areas appeared in the barrier layer next to the silver leads. The short circuit currents were much lower after lamination. This was especially true in the chemiplated barrier type cells.

A series of tests were arranged to see if the solder was usable with the electroplated grids. Care was taken to be sure there was no excess amount of solder present.

Cells were pressure tested before lamination and I-V curves obtained. The cells were then laminated (12 chemiplated and 12 electroplated) using Alpha solder, 1 mil silver leads, and unsoldered 1 mil silver leads. As a result of the tests, the Alpha solder gave no significant degradation to the electroplated cell and in most cases, an improvement. (See Table III) Similar results with the chemiplated cells were observed (see Table IV). The important factor seems to be the amount of solder used. If too much is used, a degradation effect is certain to take place. This degradation is doubtless due to the indium.

TABLE II

Data for Pressure Tests

Original Efficiency (P.T.U.)

Cell No.	Voc (Volts)	Isc (Ma)	Pwr (Mw.)	Area (cm ²)	Eff. (%)
S1027A	0.46	108	14.0	19.5	0.72%
S1027B	0.44	96	19.2	19.5	0.98%
S1028A	0.44	88	14.0	19.5	0.72%
S1028B	0.44	92	14.4	19.5	0.74%

After Lamination

Cell No.	Pressure (psi)	Voc (Volts)	Isc (Ma)	Pwr (Mw.)	Area (cm ²)	Eff. (%)	% Increase
S1027A	150	0.44	248	64	21.5	2.97	312
S1027B	200	0.40	240	47	19.5	2.41	146
S1028A	100	0.45	240	59.8	21.8	2.47	280
S1028B	250	0.41	200	26.0	18.2	1.43	91

TABLE III

Data of Alpha Solder Tests

Electroplated Barrier

Cell No.	<u>Before Lamination</u>			Alpha Soldered Leads	<u>After Lamination</u>		
	Voc	Isc	Eff		Voc	Isc	Eff
	(Volts)	(Ma.)	(%)		(Volts)	(Ma.)	(%)
Z69C#1	0.45	72	1.60		0.46	83	2.48
Z69C#3	0.46	71	1.60		0.47	80	2.17
Z74D#2	0.49	70	1.26		0.43	80	1.91
Z74D#3	0.44	68	1.75		0.46	80	2.46
Z77D#2	0.46	63	2.00		0.46	66	2.20
		AVER.	1.70			AVER.	2.25

Cell No.	<u>Before Lamination</u>			Non Soldered Leads	<u>After Lamination</u>		
	Voc	Isc	Eff		Voc	Isc	Eff
	(Volts)	(Ma.)	(%)		(Volts)	(Ma.)	(%)
Z69C#2	0.45	68	1.50		0.47	68	2.12
Z69C#4	0.45	70	1.67		0.47	72	2.16
Z74D#1	0.42	70	1.55		0.48	78	1.64
Z74D#4	0.41	60	1.24		0.48	78	3.10
Z77D#1	0.47	58	2.01		0.46	62	1.88
Z77D#4	0.46	58	1.98		0.46	64	2.12
		AVER.	1.66			AVER.	2.17

TABLE IV

Data of Alpha Solder Tests

Chemiplated Barrier

Cell No.	<u>Before Lamination</u>			Alpha Soldered Leads	<u>After Lamination</u>		
	Voc (Volts)	Isc (Ma.)	Eff (%)		Voc (Volts)	Isc (Ma.)	Eff (%)
S1046-2-2	0.42	92	2.64		0.38	111	2.70
S1049-2-1	0.39	78	1.44		0.38	91	1.95
S1054A-1	0.40	66	1.88		0.36	95	2.20
Z127C4-2	0.40	60	1.88		0.38	80	2.24
S1064-2	0.40	140	1.25		0.36	120	1.12
S1065-2	0.35	160	1.10		0.37	160	1.69
		AVER.	1.70			AVER.	1.98

Cell No.	<u>Before Lamination</u>			Alpha Soldered Leads	<u>After Lamination</u>		
	Voc (Volts)	Isc (Ma.)	Eff (%)		Voc (Volts)	Isc (Ma.)	Eff (%)
S1046-2-1	0.40	75	2.06		0.40	96	2.38
S1049-3-2	0.41	80	1.89		0.39	98	2.20
S1054A-2	0.38	52	1.25		0.38	81	2.40
Z127C4-1	0.42	68	2.00		0.38	90	2.38
S1064-1	0.40	168	1.62		0.40	184	2.29
S1065-1	0.28	168	0.80		0.40	160	2.09
		AVER.	1.60			AVER.	2.29

PILOT LINE

During this quarter, one hundred and two cells were made on the standard line. The average efficiency was slightly over 2% and the highest efficiency was 2.7% when tested on the pressure test unit and 3.3% when tested after lamination. As can be seen from this last statement, the data from the pressure test unit and that gained from the cells after lamination do not seem to agree. Lately, the pressure test unit has been giving significantly lower readings. To help correct this situation, a new pressure test unit has been designed⁽⁸⁾ and fabricated (see Figure II). Several improvements have been incorporated. These include a better diaphragm arrangement, elimination of the hand clamps, and improved electrical contacts. One problem still being studied is a better method of attaching the gold grid to the lucite window.

For months there has been a suspicion that something in the solar cell process was wrong. The evidence pointed to the transistor washer used to rinse the cells after electroplating. The conductivity of the water remained high but the efficiency of the cells was down. When the washer was installed over two years ago, it contributed from one-half to one percent increase in efficiency to the individual cell efficiency. Recently, the average efficiency has been down about one percent. Finally, the washer problem became large enough to become apparant. It started with a jelly-like substance plugging the sub-micron filters. The source of this contamination was traced to the organic removal cartridge. The manufacturer has informed us that the manner in which these cartridges are packaged is not sufficient to prevent fungus growth. The washer is now being cleaned and decontaminated. As soon as the new cartridges arrive, they will be installed and it is expected that the one-half to one percent increase in efficiency will be regained.

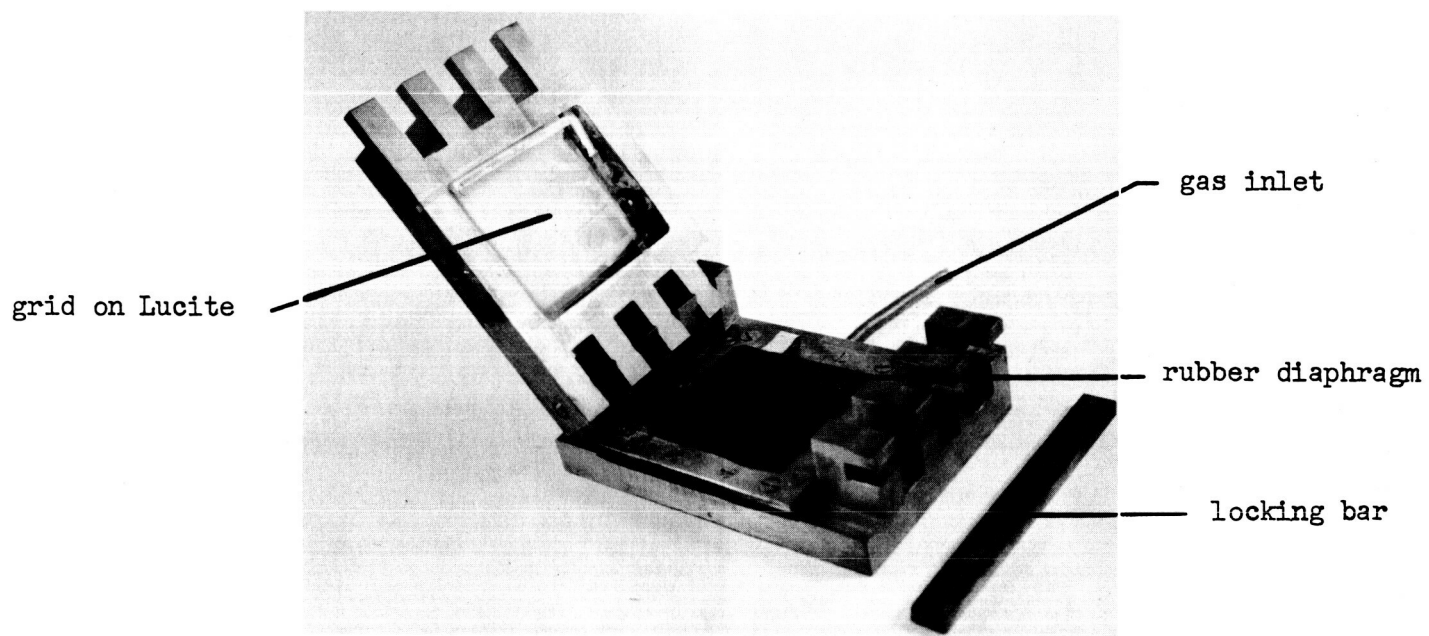


Fig. II Pressurized solar cell test apparatus

WORK PLANNED FOR THE NEXT QUARTER

1. Efforts to get finer control of the chemical milling process will continue. Combination of strong and weak acid solutions will be used. The search for another type etchant will be extended.
2. Electroplated grid work will still be scheduled. Emphasis will be placed on methods of attaching bus bars. The possibility of eliminating so many shorted cells will be examined.
3. An examination of the early stages of film growth will be made.
4. Work will be continued on other substrate materials, especially titanium, invar, and clad metals.
5. The impulse laminator will be modified for use on solar arrays. More work will be done on laminating at different pressures.
6. Pyre M.L. varnish, and other high temperature moisture proof coatings will be examined.
7. Some work will be initiated on sintering CdS on substrates.
8. The uniformity of the junction will be examined.

REFERENCES

1. & 2. T. A. Griffin, R. W. Olmsted, and J. C. Schaefer, Research and Development in CdS Photovoltaic Film Cells, NASA CR-54108, Contract NAS3-2493, p 17.
3. J. C. Schaefer, R. J. Humrick, R. F. Belt, Investigation of Thin Film Cadmium Sulfide Solar Cells, Second Quarterly Report, AF33(615)-1248, Task No. 81730-32, 9 August 1964.
4. T. A. Griffin, J. C. Schaefer, R. W. Olmsted, Fifth Period Progress Report Research and Development in CdS Photovoltaic Film Cells, Contract NAS3-2493, 26 November 1963, p 8.
5. Microwelder Mark 11, Aerojet-General Corporation.
6. & 7. E. I. duPont de Nemours & Co., Inc.
8. Donald J. Harvey, Norman E. Heyerdahl, Research on Photovoltaic Cells, Ninth Quarterly Progress Report, Contract AF33(657)-7916, Project 7885, August, 1964, p 11.

FINANCIAL SECTION

Personnel

Approximate time devoted to this contract by the principal technical personnel and other supporting personnel during the first quarter were as follows:

<u>Personnel</u>	<u>Hours</u>
J. C. Schaefer	113
T. A. Griffin	428
R. W. Olmsted	373
W. W. Baldauf	128
D. H. Dickey	162
R. F. Belt	50
Others	1150

Cost for First Quarter (to August 15)	20,682.00
Remaining funds for cost	<u>71,263.00</u>

TOTAL 91,945.00